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PHOSPHATE REMOVAL BY BIOLOGICAL PROCESS

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31 May 1969

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PB 215 505

FINAL REPORT

OF

DEMONSTRATION PROJECT WPD 173

SUBMITTED TO THE

DEPARTMENT OF THE INTERIOR

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

BY

CITY OF TRENTON ENGINEERING DEPARTMENT

2707 RIVERSIDE DRIVE

TRENTON, MICHIGAN

By: *Timothy L. Hennessey,*
City Engineer

Date: *May 31, 1969*

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PHOSPHATE REMOVAL BY BIOLOGICAL PROCESS

Introduction

The purpose of the Pilot Plant installed at the City of Trenton was to establish the efficacy of removing phosphorous from waste water using a biological system. The project was initiated on February 1, 1967 and continued through to May 31, 1969. The major activities of this project were, the design and fabrication of the two 10 gpm activated sludge process units; the determination of the operating parameters which result in phosphorous removal and the operation of continuous flow through system utilizing acid stripping modification of conventional activated sludge for phosphorous removal.

Prior to adopting acid stripping as a means of increasing phosphorus removals, batch studies were made using both acid stripping and anaerobiosis to determine which method would achieve the best degree of phosphorus removal. Studies utilizing waste pickle liquor were made during the latter part of the grant period to determine its effectiveness in removing phosphorus both in stripping and precepitation and in primary clarifyer precipitation and settling. These latter studies have shown economical effective answers for the City of Trenton and the Detroit area in general but the true efficacy of a modified activated sludge phosphorus removal process has not been established.

Design, Fabrication and Installation of the Modified Pilot Unit

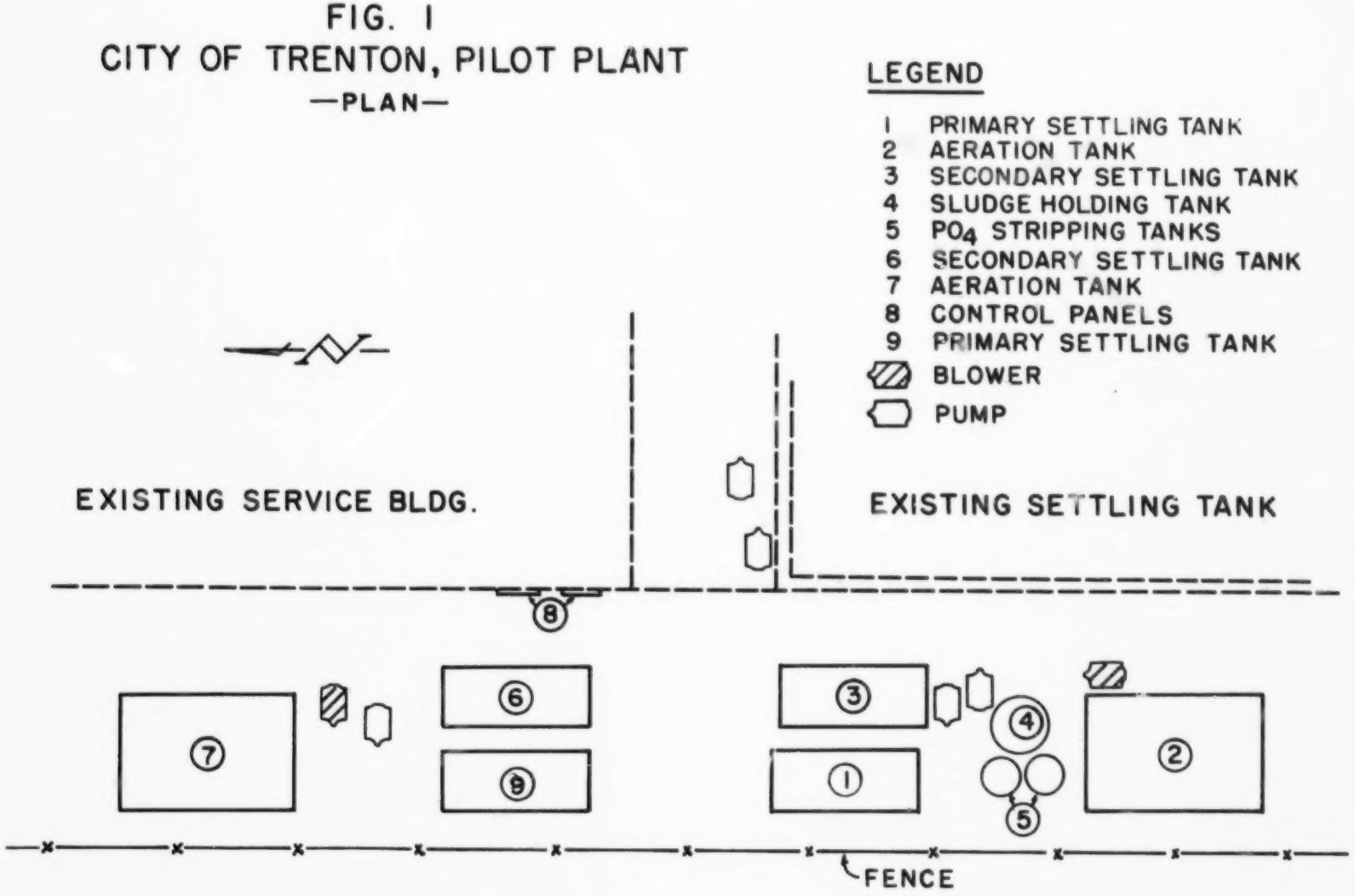
As indicated above, the original pilot operation consisted of two completely independent units operated in parallel. These units were designed as true prototypes using current design standards. Each unit consisted of a primary settling basin, aerator and secondary clarifyer. In addition three smaller sludge holding tanks were included to facilitate phosphorus stripping by batches. No other accommodations were included for complete sludge treatment in this initial stage and waste sludge merely emptied into existing primary clarifyer of the waste treatment flow. Pilot plant flow was based on 10 gpm and designed accordingly.

The pilot units were located on the City of Trenton Waste Treatment Plant property. The units were installed just West of and adjacent to the existing administration building and primary clarifyers. The location of the units with respect to the surrounding area and their relationship to one another and to the existing plant is shown in Figure I. All units were of steel construction painted over with a rubber paint to prevent corrosion by the waste water. The tanks were equipped with steel legs which rested on concrete pads. The entire area was covered with large stone to allow for easier access to and around all units.

The primary clarifyers although not truly necessary for a study on aeration units were nevertheless included so a study of an overall plant could be carried out. The primary clarifyers were 4 feet wide, 10 feet long and 4 1/2 feet deep and at the normal flow rate of 10 gpm allowed an overflow rate of 423 gpd per square foot, discounting 1 1/2 feet of length for inlet and outlet structures. The depth of flow is 4 feet allowing one-half foot for freeboard. The inlet construction originally consisted of a perforated baffle to provide even distribution of waste water across the entire bank. The effluent launder was of U shape construction and because of initial difficulties, a baffle was added just ahead of the effluent channel. The primary clarifyers were also equipped with a combination skimmer and sludge scraping mechanism and sludge was scraped to the sludge hoppers at the influent end of the tank. The volume available for sludge storage is 4 1/2 cubic feet. These units have been shown to operate normally giving B.O.D. and S.S. removals as expected.

The secondary clarifyers were designed in a similar manner except that the unit size is 4 feet wide, 8 feet long and 4 1/2 feet deep, providing a slightly shorter detention period. The detention time in the secondary clarifyers was set at 1.6 hours for the normal flow rate of 10 gpm as opposed to 2 hours for the primary settling tanks. Inlet and outlet structures for the secondary settling tanks were originally similar to those of the primary.

FIG. 1
CITY OF TRENTON, PILOT PLANT
—PLAN—



The aeration tanks were designed in such a way as to provide a large amount of aeration both from the point of view of detention time and also the air supply. The final design resulted in an aeration tank 8 feet wide, 12 feet long and 4 1/2 feet deep providing approximately 5 1/2 hours of detention time at the design flow rate. This is rather long but it was felt desirable inasmuch as previous work has indicated that aeration is a major consideration in phosphorus uptake. The volume of the aeration tank is 384 cubic feet or 2880 gallons. Air supply equipment for Unit B, the experimental unit, provides for aeration rates of up to 7 cfm per gallon of waste which is much higher than normal rates. Aeration in the tanks is provided by perforated pipe but in addition to this the aeration tank of Unit B is equipped with two mechanical aerators to provide additional mixing capacity.

Modifications to the original design as described above include the following:

The inlet construction of the primary and secondary clarifyers was changed to one in which the flow was split and directed through two pipes and emerged back against the influent wall of the tank to dissipate energy and provide for more even distribution of water across the tank.

Feed to the aerator was changed to a system in which the flow was directed transversely from 8 outlet pipes, four on each side, running the length of the tank.

A high-rate tube settler was installed at the effluent end of the secondary clarifyer. This unit was of original design and was constructed on the site from corrugated fibreglass sheets sandwiched together in such a way as to create tubes two feet long, approximately 1-1/2" in diameter and inclined at an angle of 60° to horizontal flow.

The primary and secondary clarifyers of Unit A were incorporated into the flow pattern of Unit B in the following way:

Sludge to be stripped was pumped from the hoppers in the bottom of unit B into the primary clarifyer of Unit A where it was mixed with 66^{0} Bé H_2SO_4. The sludge from the hoppers of this tank was then pumped into Unit A secondary clarifyer where it was mixed with service water, settled, and pumped back into Unit B aerator as stripped, washed sludge.

OPERATIONAL REPORT

The facility consists of two complete activated sludge process units designated as Unit A and Unit B. Unit A was the control unit which was to be operated under normal conditions and Unit B was the unit in which the operational parameters were changed in order to determine the operating conditions which result in the best removal of phosphorus. The raw waste water pumps and return sludge pumps are driven by variable speed motors which permit the plant to be operated at different gpm capacity. The compressor supplying the air to the aeration tank is also powered by a variable-speed motor which permits the plant to be operated between the ranges of 1 and 10 cfm/gal. of waste water.

The results of the San Antonio Plant were used as a guide to determine the parameters which should be varied to establish the optimum operating conditions for phosphorus removal. These parameters are: 1) Aeration time and quantity of air supplied: 2) Concentration of mixed liquor suspended solids; 3) Concentration of dissolved oxygen in the aerator. Dr. H. A. Dirasian, the consultant Sanitary Engineer for this project, was responsible for the design of the units. He also advised the Pilot Plant staff during the operational tests. A 24-hour composite sampling was made on influent and the effluent, and BOD, suspended solids and ortho phosphate determinations were made on these samples. During this test period, the amount of air per gallon of waste water and the MLSS were varied in an effort to select operating conditions which would remove ortho phosphate. Table I shows BOD, suspended solids and ortho phosphate removed for Unit A and B during this experiment. From these results it was evident that the operating conditions which resulted in the removal of phosphorus in the San Antonio (Rilling) Waste Treatment Plant did not produce the same results in Trenton. As you will note from Table I, the influent waste has a low BOD with average phosphorus concentration.

TABLE I

BOD, SUSPENDED SOLIDS, AND PO_4 REMOVAL IN UNIT A & B WITH VARYING AIR & MLSS

Date Oct. 1967	Unit	Air ft./ gal.	MLSS mg/l	BOD Infl.	BOD Prim. Mg/l	BOD Effl. Mg/l	BOD % Rem.	Suspended Solids Infl.	Suspended Solids Prim. Mg/l	Suspended Solids Effl. Mg/l	Suspended Solids % Rem.	Ortho Phosphate as P Infl.	Ortho Phosphate as P Prim. Mg/l	Ortho Phosphate as P Effl. Mg/l	Ortho Phosphate as P % Re
1	A	3.0	2428	152.0	110.6	24.2	84.0	190	94	52	72.6	5.5	6.8	7.5	None
	B	4.5	1458		112.0	23.8	84.3			58	69.5		4.5	6.3	"
2	A	3.0	2537	160.5	135.0	13.1	88.8	172	132	42	75.6	5.6	4.9	6.3	"
	B	4.5	1553		117.2	31.6	80.4		100	98	43.1		5.9	5.2	6.5
3	A	2.7	2505	141.9	147.2	19.5	86.3	172	126	46	73.3	3.0	3.3	6.3	None
	B	4.5	1473		133.2	43.0	69.7		118	98	43.1		4.6	5.2	"
4	A	2.7	1863	191.8	98.0	12.2	93.6	246	116	34	86.2	4.2	4.0	4.4	"
	B	4.5	1340		117.9	56.8	70.4		214	90	63.5		4.4	4.3	"
5	A	2.7	1853	137.2	133.0	16.3	88.1	188	84	32	83.0	-	-	-	-
	B	4.5	1513		107.0	26.8	80.5		90	90	52.2	-	-	-	-
6	A	2.7	1575	185.1	112.5	31.5	83.0	208	34	42	98.0	5.3	4.1	5.0	6.2
	B	5.5	1290		132.2	-	-		76	164	20.4		4.6	4.6	13.6
7	A	2.7	1940	146.5	98.5	28.5	80.5	190	98	50	73.7	7.1	5.9	7.1	None
	B	5.5	1555		103.9	34.2	76.7		94	80	57.9		8.0	6.0	14.7
8	A	2.7	2110	-	128.5	11.8	90.2	234	66	-	-	4.7	4.9	6.0	None
	B	5.5	1750	-	120.5	45.0	62.8		94	58	75.2		4.6	4.8	None
9	A	2.7	2300	150.5	111.9	191.1	87.3	198	156	54	72.7	4.9	5.1	6.4	None
	B	4.5	2030		129.9	69.2	55.0		140	80	59.6		4.9	3.8	21.3
10	A	2.8	1960	131.2	121.9	25.2	84.3	198	76	18	90.9	5.1	5.8	6.6	None
	B	4.5	2570		133.6	46.4	71.2		94	108	45.5		5.2	6.2	None
11	A	2.8	2678	151.2	85.5	25.4	83.2	174	76	48	72.5	5.7	5.4	5.8	None
	B	4.5	2685		123.9	54.6	63.9		116	104	40.3		5.2	4.4	22.2
12	A	2.8	3110	177.8	94.6	29.4	83.5	184	72	36	80.4	5.9	6.4	7.1	None
	B	4.5	2485		129.2	61.4	65.5		92	90	51.1		5.6	4.6	21.7

TABLE I (page 2)

BOD, SUSPENDED SOLIDS, AND PO_4 REMOVAL IN UNIT A & B WITH VARYING AIR & MLSS

Date Oct. 1967	Unit	Air ft./ gal.	MLSS mg/l	Infl.	BOD Prim. Mg/l	BOD Effl. Mg/l	BOD % Rem.	Suspended Solids Infl. Mg/l	Suspended Solids Prim. Mg/l	Suspended Solids Effl. Mg/l	Suspended Solids % Rem.	Ortho Phosphate as P Infl. Mg/l	Ortho Phosphate as P Prim. Mg/l	Ortho Phosphate as P Effl. Mg/l	Ortho Phosphate as P % Rem.
13	A	2.8	2843	210.5	157.8	26.0	87.7	294	108	62	79.0	6.9	5.9	7.2	None
	B	4.5	663		152.2	44.0	79.1		126	86	70.8		7.1	6.1	11.8
14	A	2.8	3000	157.2	133.9	27.4	82.6	184	108	40	78.3	5.4	6.4	6.5	None
	B	4.5	1117		129.2	35.6	77.4		128	88	52.2		6.6	5.9	"
15	A	2.8	3152	186.5	93.2	19.4	89.6	374	130	26	93.0	2.2	2.4	3.8	"
	B	4.5	1578		85.5	60.8	67.4		112	92	75.4		2.3	3.6	"
16	A	2.8	3001	128.5	79.9	22.2	82.7	238	130	34	85.7	1.8	2.1	3.5	"
	B	4.5	1595		72.0	62.2	51.6		112	116	51.3		2.0	2.8	"
17	A	2.8	2643	53.5	24.0	9.4	82.4	254	74	28	89.0	1.1	1.0	2.0	"
	B	4.5	1603		26.5	34.6	34.6		84	102	59.8		0.7	1.8	"
18	A	2.8	2280	61.9	73.5	8.5	88.5	194	60	20	89.7	1.7	1.3	2.6	"
	B	4.5	1898		34.6	34.1	53.7		52	50	74.2		1.4	1.9	"
19	A	2.8	2202	101.9	63.0	14.0	86.3	188	82	20	89.4	2.2	2.5	3.0	"
	B	4.5	1840		69.0	43.0	57.9		142	94	50.0		2.7	4.3	"
20	A	2.8	2300	110.5	48.6	10.0	91.0	232	42	36	84.5	1.5	1.7	3.0	"
	B	4.5	1800		84.0	26.3	76.3		120	78	66.4		2.1	2.6	"
21	A	2.8	2630	114.6	74.6	10.5	90.9	180	68	46	74.5	5.6	5.3	6.2	
	B	4.5	2063		94.3	25.1	78.2		80	66	63.3		4.9	4.6	16.1
22	A	2.8	2800	115.2	65.3	35.0	70.0	154	74	22	85.7	6.4		5.7	12.5
	B	4.5	2302		117.9	26.2	77.2		138	68	55.9		8.9	8.4	None
23	A	2.8	2640	165.1	114.0	19.4	88.2	206	68	20	90.3	5.7	6.9	9.5	None
	B	4.5	2210		107.0	33.2	79.9		106	44	78.6		1.0	4.8	14.6
24	A	2.8	2115	132.5	98.6	11.4	82.4		154	12	92.3		26.1	13.2	
	B	4.5	745		110.0	36.1	72.9		232	34	78.2		6.7	5.5	

TABLE I (page 3)

BOD, SUSPENDED SOLIDS, AND PO_4 REMOVAL IN UNIT A & B WITH VARYING AIR & MLSS

Date Oct. 1967	Unit	Air ft./ gal.	MLSS mg/l	BOD Infl.	BOD Prim. Mg/l	BOD Effl. Mg/l	BOD %Rem.	Suspended Solids Infl. Mg/l	Suspended Solids Prim. Mg/l	Suspended Solids Effl. Mg/l	Suspended Solids %Rem.	Ortho Phosphate as P Infl. Mg/l	Ortho Phosphate as P Prim. Mg/l	Ortho Phosphate as P Effl. Mg/l	Ortho Phosphate as P % Rem.
25	A	2.8	2113	179.8	81.9	16.3	90.9	268	62	54	79.8	4.1	3.6	16.3	None
	B	4.5	1318		123.8	45.6	74.7		138	72	73.2		6.2	12.3	None
26	A	2.8	2303	175.8	91.9	17.6	90.0	210	82	48	77.2	5.6	4.6	6.5	None
	B	4.5	2560		135.2	38.2	78.3		154	58	72.4		5.4	5.3	
27	A	2.8	2095		Shut down for repairs										
		4.5	2430												
28	A	2.8	-	145.8	85.2	35.4	75.8	154	64	34	77.9	4.5	4.0	5.0	None
	B	4.5	-		93.9	34.6	76.3		96	46	70.1		4.6	4.8	None
29	A	2.8		195.0	122.5	18.5	90.5	204	164	50	75.5	3.9	3.9	4.7	None
	B	4.5			112.5	17.8			158	52	74.6		3.8	4.8	None
30	A	2.8		187.8	141.2	16.5	91.2		136	42	85.0		5.7	6.8	None
	B	4.5			123.9	16.6	91.2		124	30	89.3		5.2	6.4	None
31	A	2.5		173.8	82.6	16.6	90.5	256	108	20	86.6	2.8	3.7	5.1	None
	B	4.5			94.5	29.8	82.9		164	24	89.9		3.5	5.3	None

In the results presented in Table I, the BOD and suspended solids removals were satisfactory even though the phosphorus removal was poor and erratic. The amount of diffused air per gallon of waste water in these tests ranged from 1.8 to 5.5 cu. ft. per gal. of waste water and the MLSS ranged from 1,000 to 4,000 mg/l. The varying of the MLSS and rate of aeration did not appreciably change the amount of phosphorus removed. It was felt that part of the reason for poor phosphorus removal was due to the low C/P ratio present in the waste water. Further data seemed to indicate that bacteria in this process quickly reached "saturation", and unless this excess phosphorus were removed, no more luxury uptake was possible.

Again following the lead of Levin, we tried both acid and anaerobic stripping, first in batch scale experiments and later with continuous flow-through studies. Results of the anaerobic stripping run showed the release of phosphorus with time from organisms held under anaerobic conditions to be excessive. To obtain large releases it was decided to use acid stripping which produced the same release levels of phosphorus as with anaerobic stripping but in a shorter length of time. The results of Anaerobic Stripping of Soluble Phosphate PO_4 are shown in Figure II.

These results led to the next step in our process, namely the conversion of the primary and secondary clarifyers of Unit A to stripping and wash tanks for the continuous, flow-through system it was felt was necessary.

pH in the stripping tank was controlled, using 66^{o} Bé H_2SO_4 pumped into contact with the sludge to be stripped on signal from a pH control system set up to maintain the pH between pH_4 and pH_5.

As previously mentioned, see Figure III, this stripped sludge was then pumped into the secondary clarifyer of Unit A where it was mixed with phosphorus-free service water to elutriate any absorbed phosphorus which might still have been clinging to the matrix of the sludge. From the wash tank the sludge was returned to the aerator where it assumed its primary function of phosphorus

FIG II
CITY OF TRENTON, PILOT PLANT

ANAEROBIC STRIPPING OF SOLUBLE PHOSPHATE PO_4

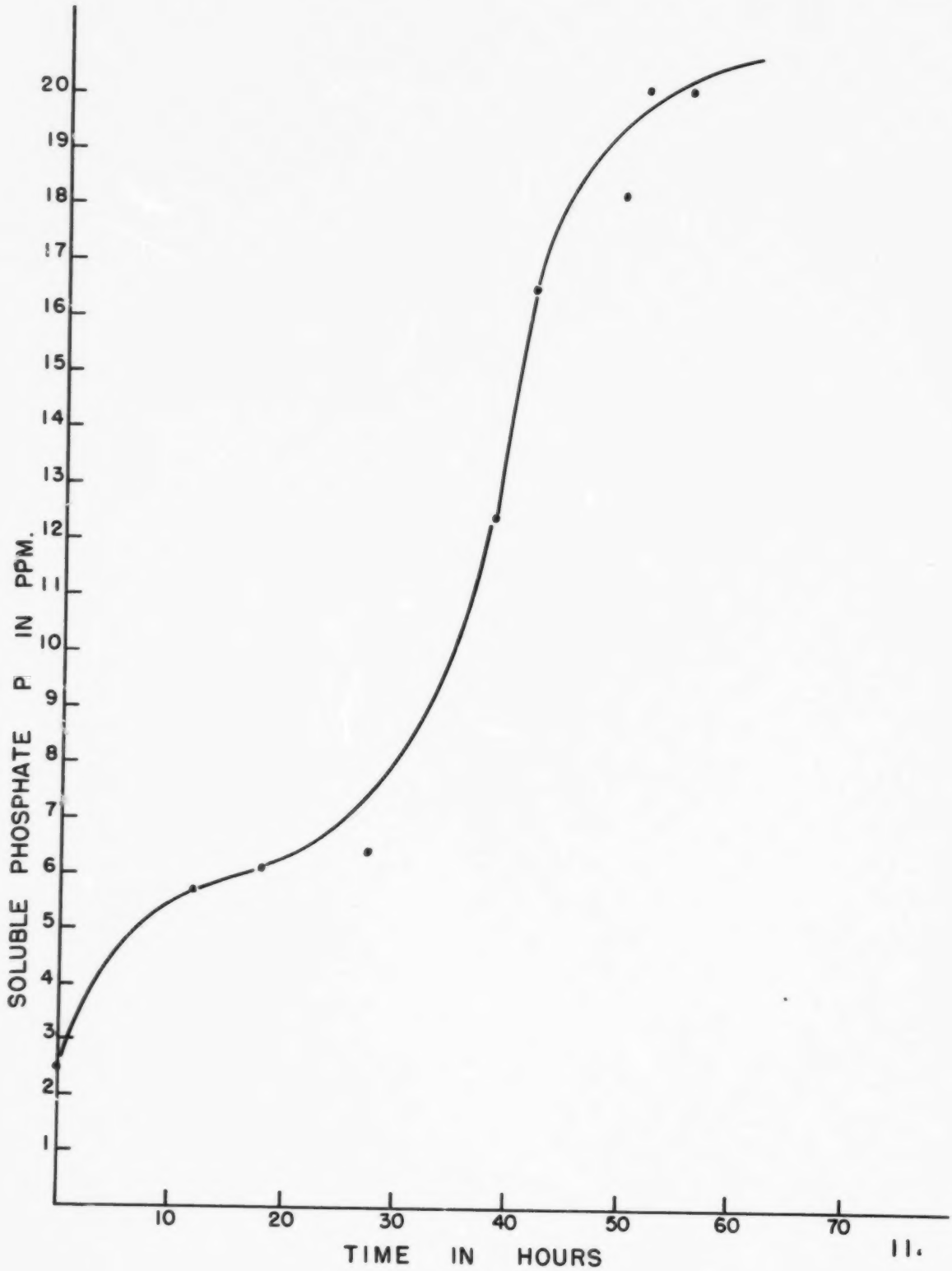
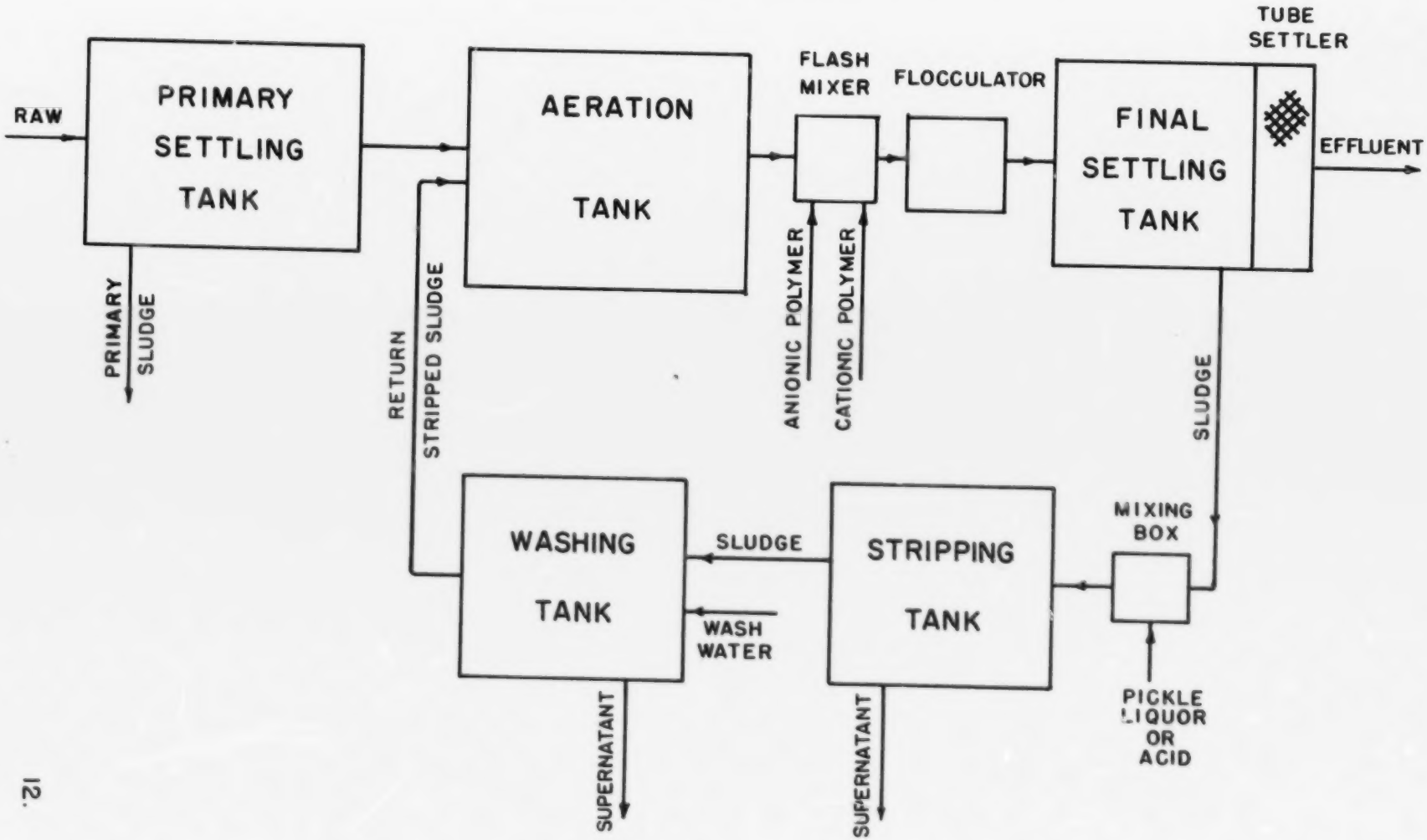


FIG III
CITY OF TRENTON, PILOT PLANT
— FLOW DIAGRAM —



uptake. It was found that these mixing and pumping operations broke up the sludge floc to the extent that it became necessary to add polyelectrolyte coagulant aids to establish good settling characteristics of floc in not only the secondary clarifyer, but in the stripping and wash tanks as well.

Studies of flow characteristics of the entire system were also conducted during this period using a Turner fluorometer and Eosin B dye. These studies indicated that some short-circuiting was present in both primary and secondary clarifyers. This situation was remedied in the primary clarifyer by changing the inlet construction as mentioned previously. In the secondary clarifyer not only was the inlet construction changed but the high-rate tube settler was also added to insure good settling characteristics in the secondary effluent.

The results from the Acid Stripping method are shown in Table 2, 3, 4 and 5 and Figures IV, V, VI and VII. The average suspended Solid Removal was 94%, B.O.D. removal 87%, Ortho-phosphate 64% and total phosphorous 69%.

Biological studies were conducted with the cooperation of Consultant Dr. H. W. Rossmore at Wayne State University. These consisted of plate counts and identification procedures done on both acid-stripped sludge organisms and aerator solids organisms which were held at various pH's for varying lengths of time. Bacterial ultrastructure investigations and the fate of sorbed phosphorus were also to be a part of these investigations but time has not permitted their completion.

TABLE 2

PILOT PLANT

CITY OF TRENTON

SUSPENDED SOLID REMOVAL

8/23/68 - 9/2/68

	MLSS (PPM)	RAW (PPM)	PRI (PPM)	EFFL (PPM)	% REM
8/23	1701	138	102	10	93
8/24	1703	142	84	20	86
8/25	1620	180	90	11	94
8/26	1773	180	114	11	94
8/27	1863	140	114	12	92
8/28	1418	130	122	11	92
8/29	1260	120	76	3	97
8/30	1210	144		3	98
8/31	965	100	54	7	93
9/1	1253	118	100	6	95
9/2	1293	96	88	12	88
TOTAL		1488	964	106	1032
AVERAGE		135	96	9	94

TABLE 3

PILOT PLANT

CITY OF TRENTON

BOD REMOVAL

8/23/68 - 9/2/68

	RAW (PPM)	PRI (PPM)	EFFL (PPM)	%REM
8/23	114	96	16	86
8/24	100	103	28	72
8/25	137	105	18	87
8/26	148	134	16	90
8/27	144	120	25	83
8/28	142	114	20	86
8/29	113	107	12	90
8/30	116		12	90
8/31	114	111	12	90
9/1	114	112	13	89
9/2	79	101	13	84
TOTAL*	1321	1103	182	957
AVERAGE	120	110	16	87

TABLE 4

PILOT PLANT

CITY OF TRENTON

PHOSPHORUS REMOVAL

	TOTAL PHOSPHORUS PPM as P			ORTHO-PHOSPHATE PPM as P				TOTAL SOLUBLE PPM as P			
	RAW	EFFL	% REM	RAW	AERATOR	EFFL	%	RAW	AERATOR	EFFL	%
8/23	8.8	3.3	63	3.5	.3	1.0	72	4.3	1.2	2.0	54
8/24	8.3	2.4	71	3.5	1.3	1.2	66	4.7	2.3	2.0	58
8/25				4.1	1.9	2.1	50				
8/26	7.5	1.6	79	3.2	1.2	1.3	61	3.3	1.4	1.5	55
8/27	10.2	3.5	66	6.5	3.3	2.3	65	6.5	2.3	2.4	64
8/28	13.0	3.6	73	6.2	2.1	3.1	50	6.1	2.3	3.1	50
8/29	9.6	2.7	72	6.2	1.6	2.0	71	6.7	1.7	2.3	66
8/30	6.7	2.3	66	5.3	1.7	1.8	70	5.9	1.7	2.0	66
8/31	8.6	2.4	72	8.2	2.3	2.1	75	8.5	2.7	2 3	73
9/1	6.7	3.2	53	3.6	.9	2.3	36	3.7	2.5	2.4	35
9/2	9.1	2.9	68	7.1	2.4	2.3	68	7.6	2.6	2.6	66
Average	8.8	2.8	69	5.2	1.7	1.9	64	5.7	2.1	2.2	62

TABLE V

BACTERIAL COUNT IN MLSS

	Time							
	0 Hrs.		1 Hr.		2 Hr.		4 Hr.	
pH	pH	Count	pH	Count	pH	Count	pH	Count
3			3.2	$7x10^4$	3.3	$4x10^4$	3.1	$1x10^4$
4			4.6	$2x10^6$	4.6	$2x10^6$	4.5	$2x10^6$
5			5.4	$5x10^7$	5.4	$3x10^7$	5.2	$1x10^7$
6			6.5	$1x10^7$	6.4	$1x10^7$		$1x10^8$
Untreated	6.8	$3x10^7$						

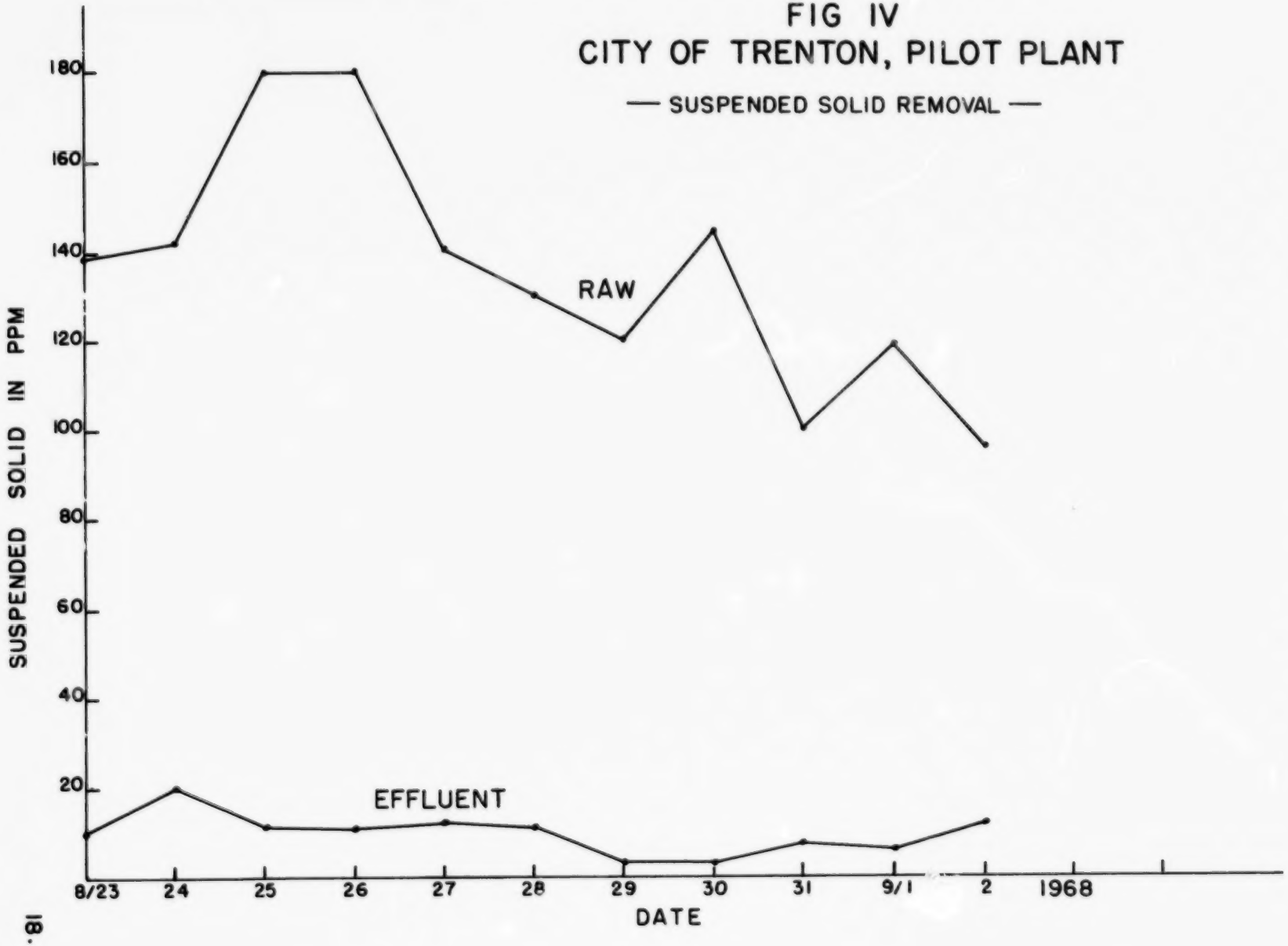
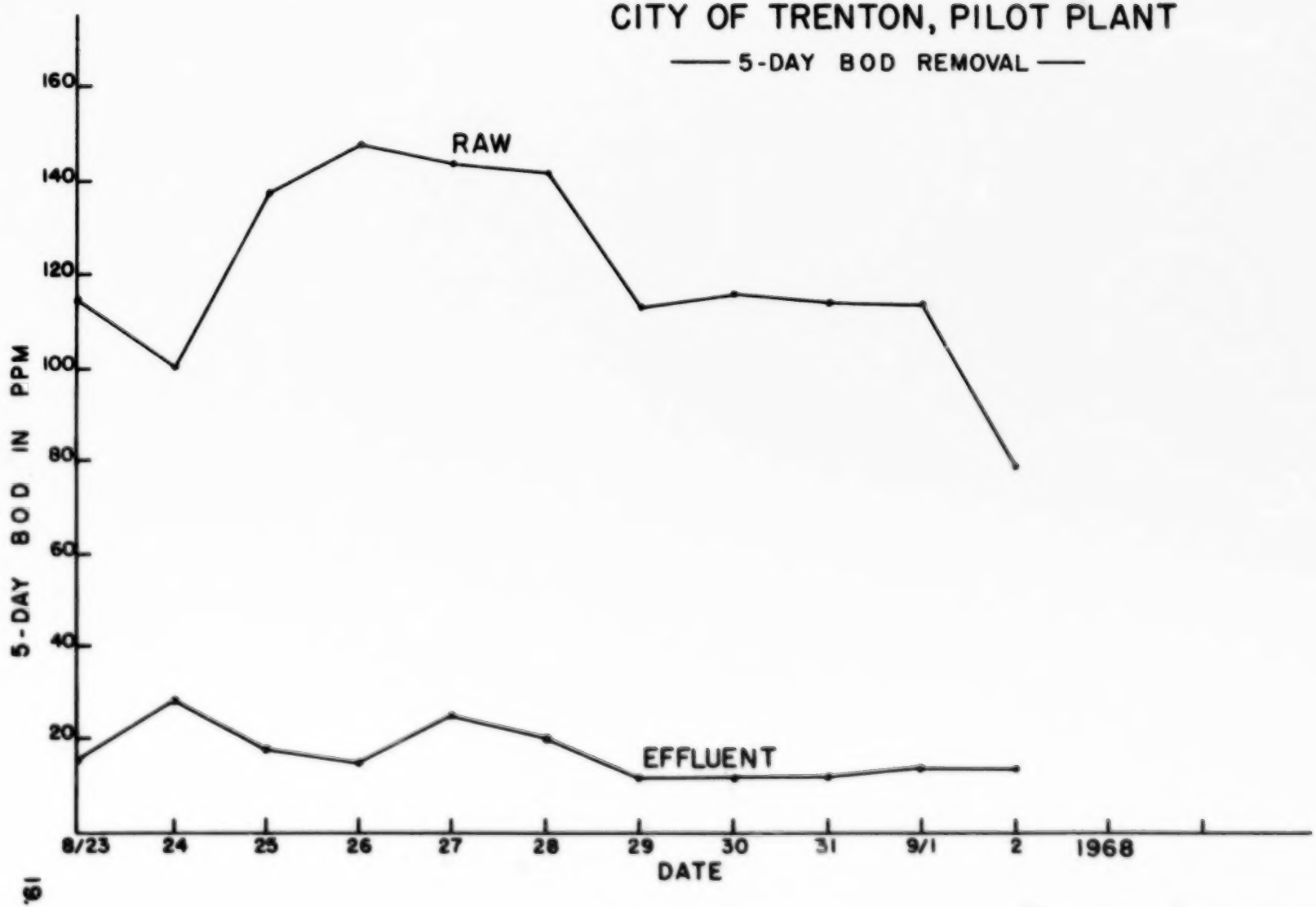


FIG IV
CITY OF TRENTON, PILOT PLANT
— SUSPENDED SOLID REMOVAL —
SUSPENDED SOLID IN PPM
180
160
140
120
100
80
60
40
20
RAW
EFFLUENT
8/23
24
25
26
27
28
29
30
31
9/1
2
1968
DATE

FIG. V

CITY OF TRENTON, PILOT PLANT

—— 5-DAY BOD REMOVAL ——



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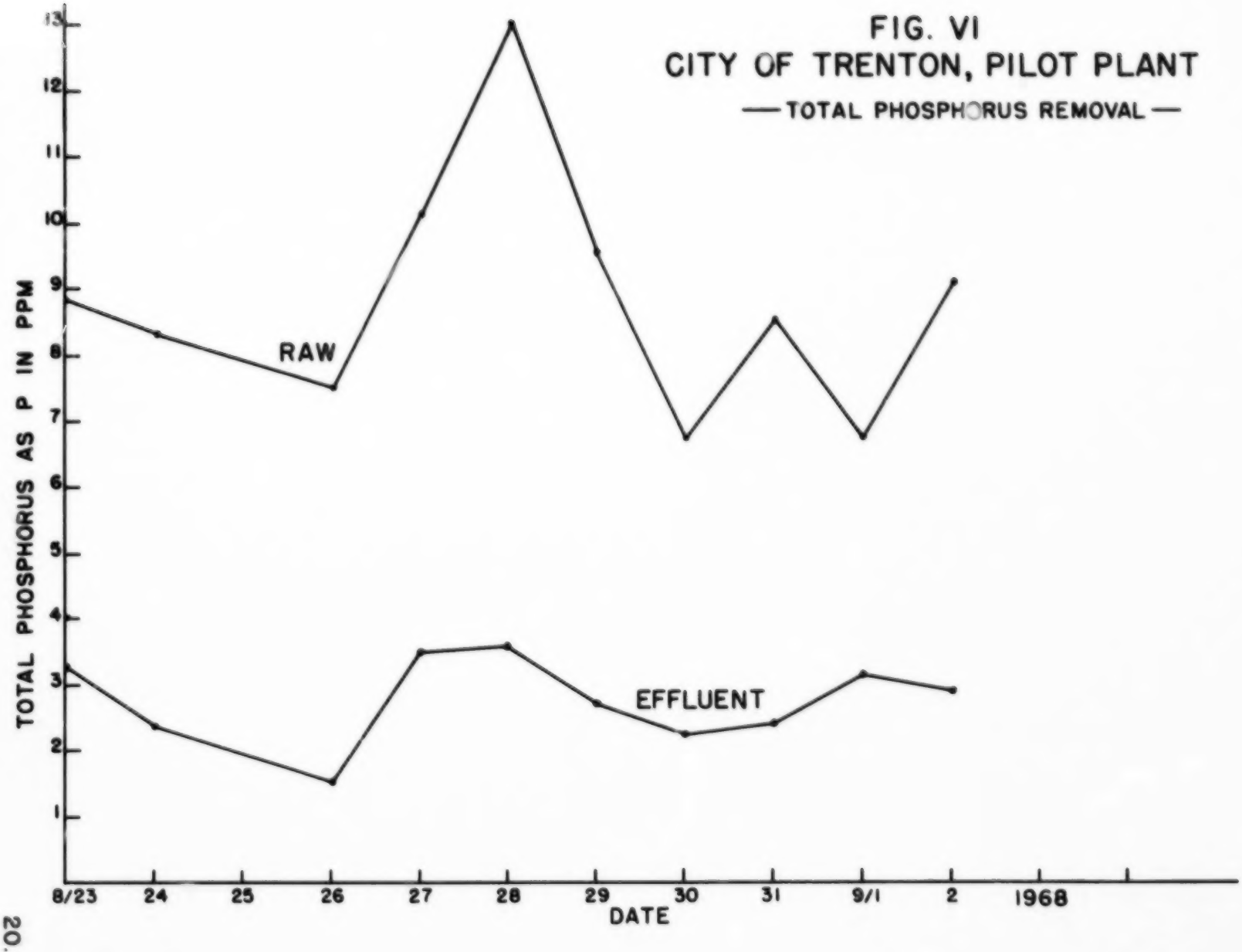
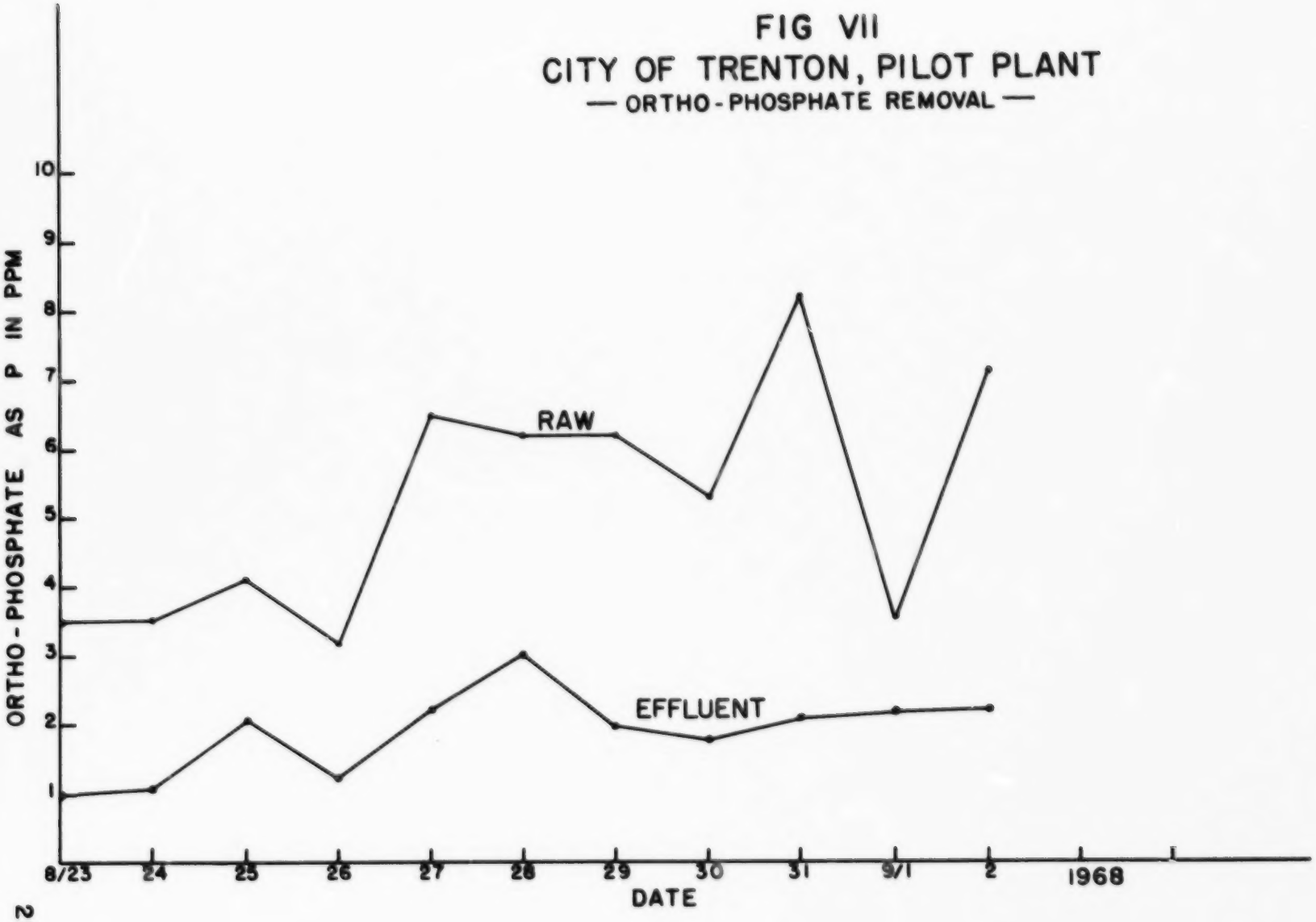


FIG. VI
CITY OF TRENTON, PILOT PLANT
— TOTAL PHOSPHORUS REMOVAL —
TOTAL PHOSPHORUS AS P IN PPM
RAW
EFFLUENT
DATE
8/23
24
25
26
27
28
29
30
31
9/1
2
1968

FIG VII
CITY OF TRENTON, PILOT PLANT
— ORTHO-PHOSPHATE REMOVAL —



In an attempt to remove phosphorus by chemical precipitation, three different trials were conducted. The first trial had as its aim the simple investigation of orthophosphate removal by ferric chloride in combination with polyelectrolyte, and was conducted using 10 ppm and 15 ppm of iron as Fe^{3+}.

The second trial employed waste pickle liquor from area steel processing plants. It was felt that application of this pickle liquor in the stripping process would accomplish two things. First, the acid present in the pickle liquor could be used to drop the pH to the desired level, pH_4 to pH_5.

Secondly, the iron present in the pickle liquor as Fe^{2+} would then combine with the released phosphate to form insoluble $Fe_3 (PO_4)2$ which would then be precipitated from the supernatant liquor.

The third application of chemical precipitation was conducted at the end of the grant period. In this trial, waste pickle liquor was diluted with service water and pumped directly into the influent end of the primary clarifyer. This approach was adopted because of the excess levels of iron which developed in the supernatant from the stripping and wash tanks in the previous trial. The low acid content (4 to 10 percent) and high iron content (12 ounces per gallon of the pickle liquor) introduced these excessive amounts of iron into the system because so much pickle liquor was required to drop the pH to the required level. Therefore, in the third trial, the pickle liquor was diluted and pumped at a rate sufficient to achieve levels of 30 to 40 ppm of iron as Fe^{2+}.

The results from addition of diluted waste pickle liquor are shown in Table VI and Figure VIII, IX, X, and XI.

TABLE VI
TRIAL USING DILUTED PICKLE LIQUOR, Fe^{2+}-30-40 PPM

	B.O.D. (ppm)					SUSPENDED SOLIDS (ppm)			
DATE	RAW	PRIMARY	EFFLUENT	% REMOVAL	MLSS	RAW	PRIMARY	EFFLUENT	% REMOVAL
12/26/68	122	104	26	79	5063	98	118	19	81
27	191	153	12	94	6328	270	94	13	95
28	59	44	7	88	6285	118	84	23	80
29	119	54	13	89	9530	166	144	18	89
30	100	80	2	98	6043	166	106	10	94
31	100	106	11	89	5390	78	72	1	99
1/1/69	45	116	4	91	6063	38	--	3	92
2	138	113	6	96	7895	224	110	3	99
3	119	178	51	57	--	118	150	18	85
4	191	115	5	98	6890	180	186	33	82
5	106	121	9	92	6113	64	182	2	97
6	205	130	12	94	6195	180	176	34	81
7	210	190	62	70	8117	272	164	1	99+
8	206	160	28	86	8015	150	130	8	95
9	112	179	62	45	7425	100	168	4	96
10	178	154	12	93	6665	140	122	4	97
11	125	138	17	86	8323	158	122	16	90
AVG.	131	118	17	87	6926	149	132	12	92

TABLE VI (page 2)

PHOSPHORUS AS P IN PPM

DATE	RAW		PRIMARY		EFFLUENT		% REMOVAL	
	TOTAL	ORTHO	TOTAL	ORTHO	TOTAL	ORTHO	TOTAL	ORTHO
12/29/68	3.4	0.82	3.3	0.10	0.72	0.20	79	76
30	5.9	1.4	5.2	1.3	1.2	0.82	80	41
31	11.3	3.2	4.7	0.26	0.85	0.78	92	76
1/[illegible]/69	5.7	1.6	3.8	0.46	1.1	0.68	81	58
2	8.3	2.4	7.5	1.4	2.4	1.2	71	50
3	8.1	5.0	8.3	1.1	1.4	0.85	83	83
4	7.0	2.9	8.2	0.39	1.6	0.59	77	80
5	9.4	6.8	6.8	1.3	1.3	0.85	86	88
6	9.5	6.1	8.2	0.75	2.0	0.65	79	89
7	10.9	1.5	9.4	0.10	1.3	0.10	88	93
8	6.9	4.1	3.1	0.03	0.28	0.05	96	99
9	15.8	3.9	8.4	0.03	2.3	0.03	85	99
10	26.8	5.1	12.1	0.17	0.34	0.04	99	99
11	13.7	5.3	13.7	6.4	2.8	0.98	80	81
AVG.	10.2	4.3	7.3	0.57	1.4	0.56	85	87

FIG. IX

CITY OF TRENTON, PILOT PLANT

SUSPENDED SOLIDS REMOVAL

AVERAGE REMOVAL 90%

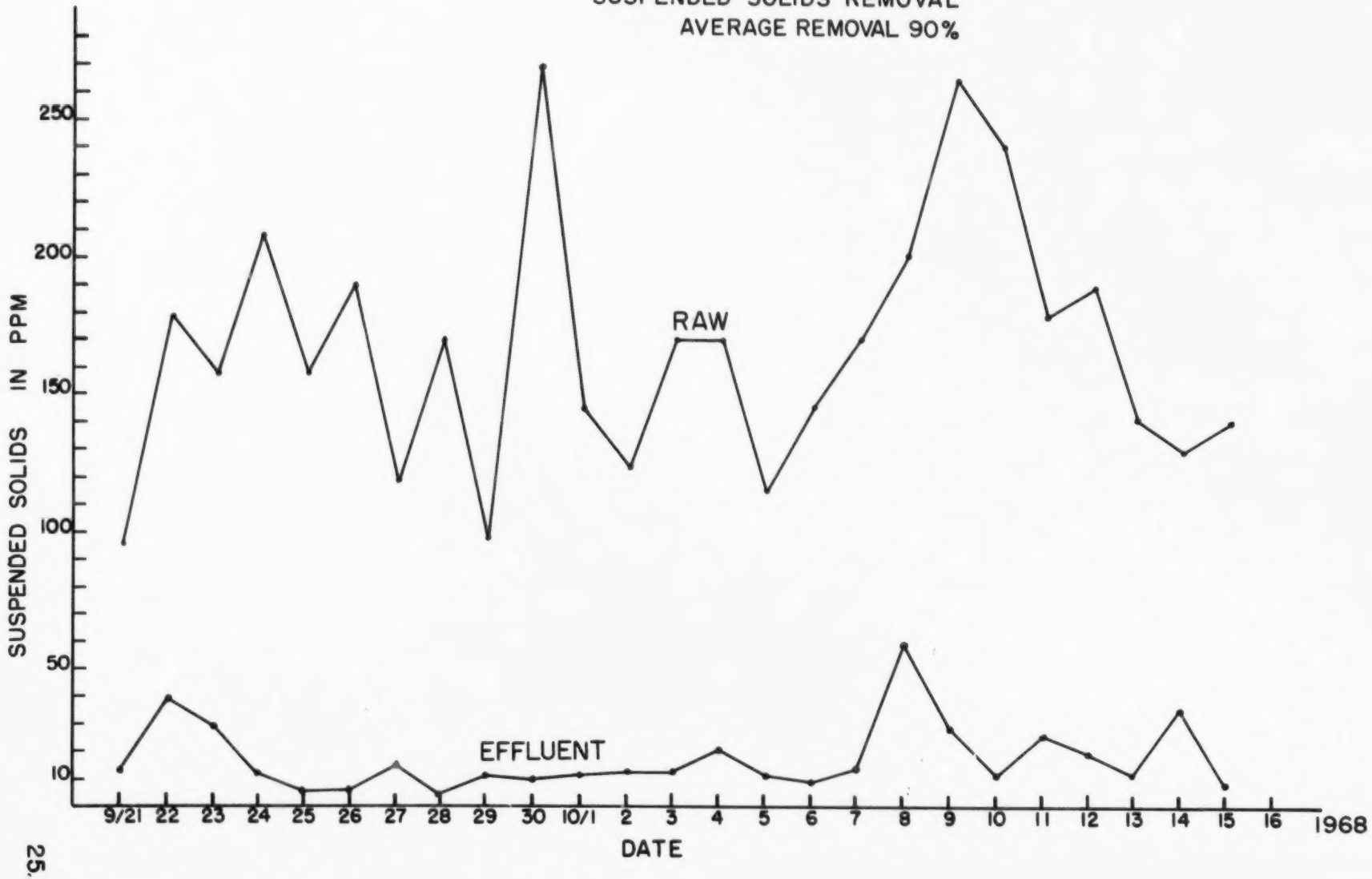


FIG VIII
CITY OF TRENTON, PILOT PLANT
5-DAY BOD REMOVAL
AVERAGE REMOVAL 90%

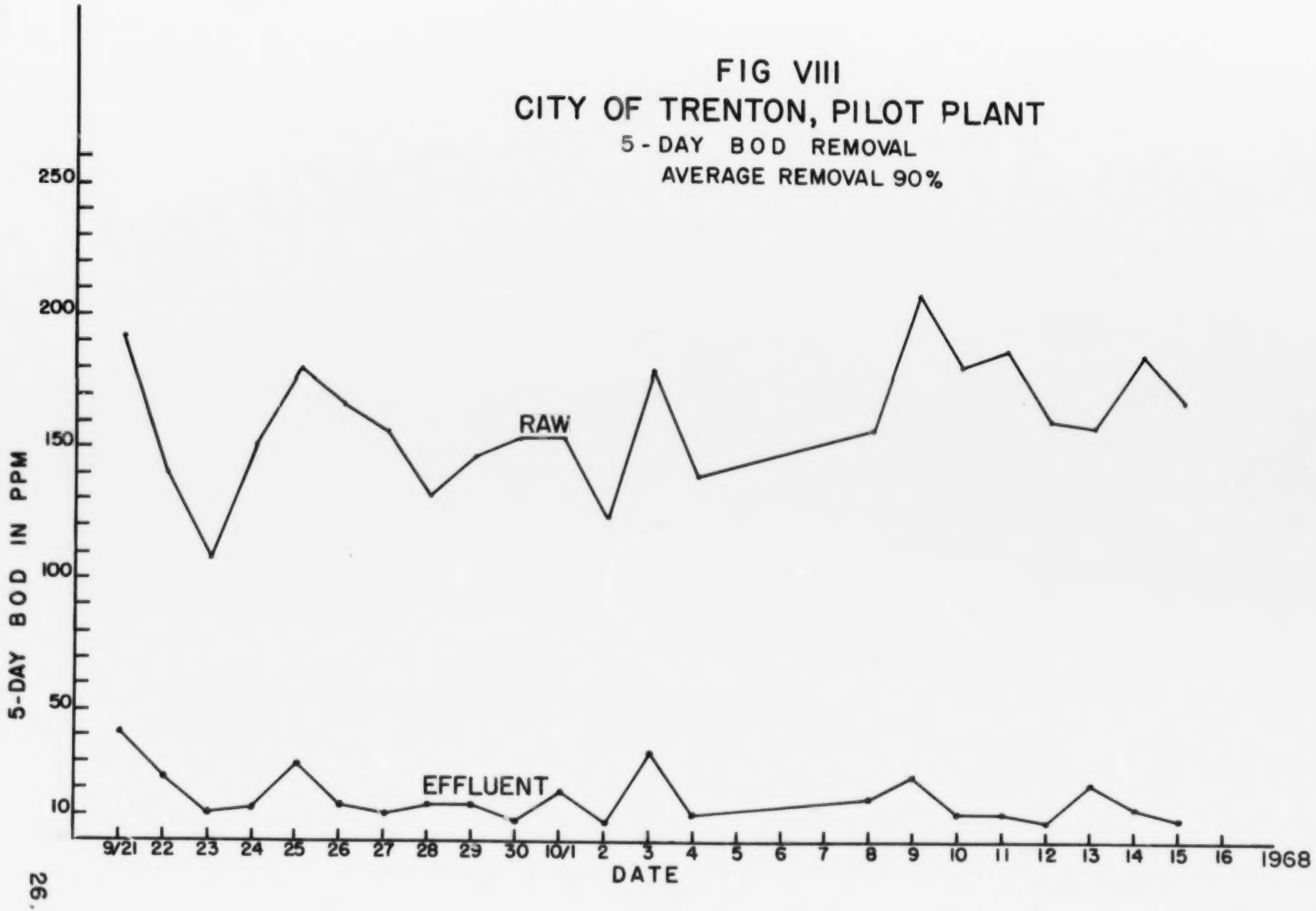


FIG. XI

CITY OF TRENTON, PILOT PLANT

TOTAL PHOSPHATE REMOVAL

USING 1 1/2 % IRON AND 7 % ACID INDUSTRIAL WASTE

AVERAGE REMOVAL 86%

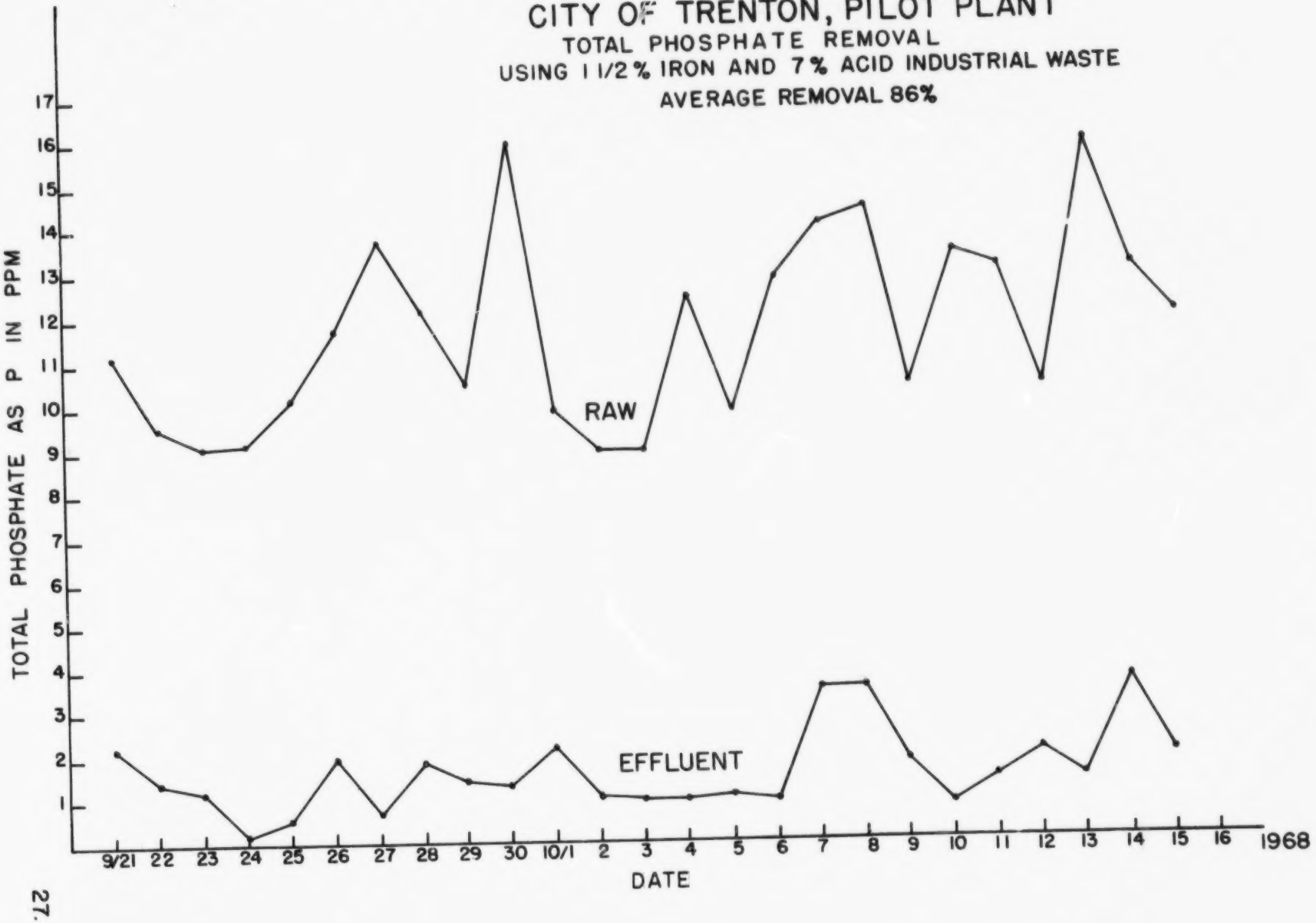
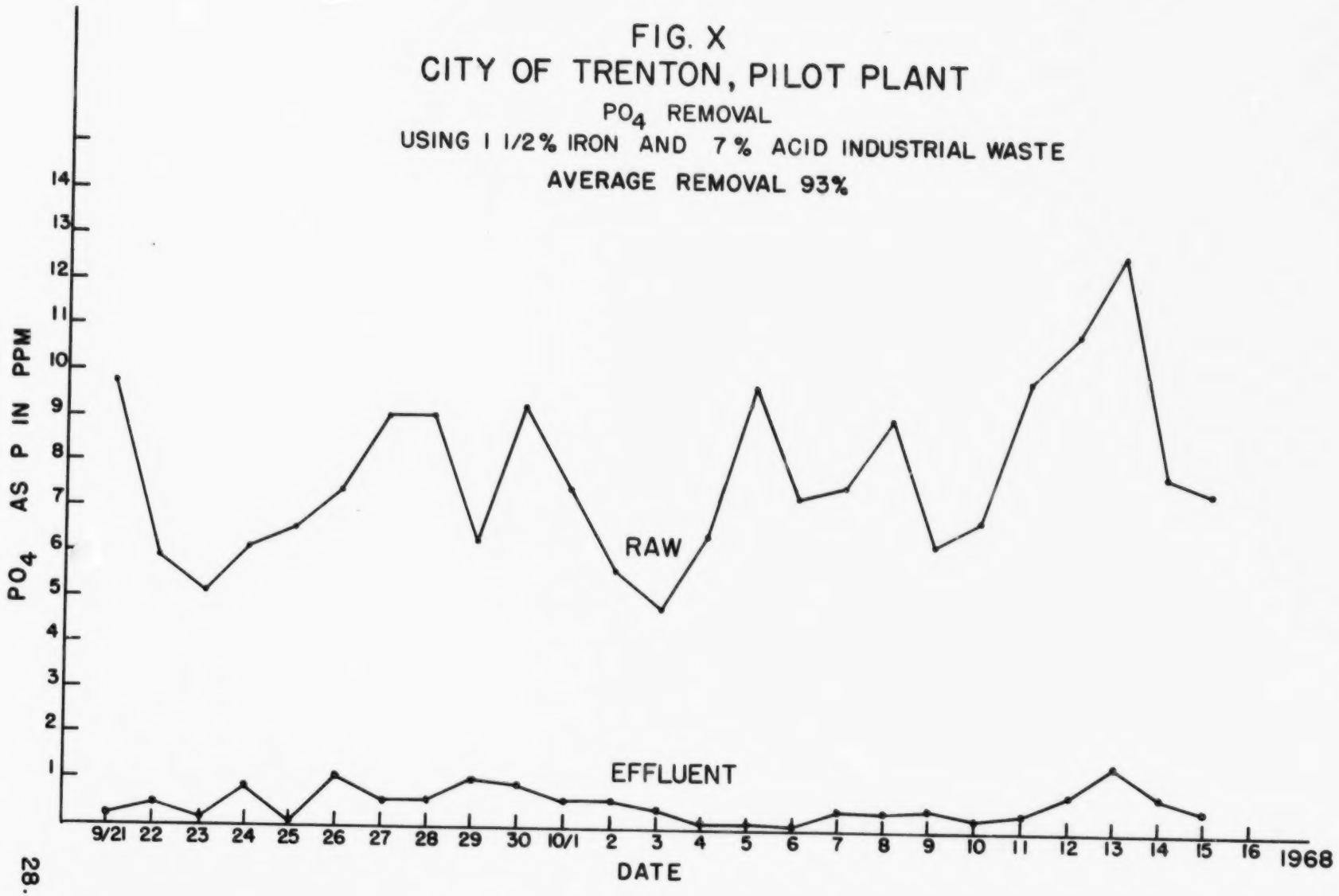


FIG. X
CITY OF TRENTON, PILOT PLANT

PO_4 REMOVAL

USING 1 1/2% IRON AND 7% ACID INDUSTRIAL WASTE

AVERAGE REMOVAL 93%



DISCUSSION

The initial aim of the experiments was to attempt to duplicate the results attained at the San Antonio Plant but it was soon found that such duplication could not be obtained. The studies were carried out in the two pilot plants: plant "A" was operated as a control while the parameters in plant "B" were varied in accordance with suggestions coming out of the Rilling Plant. The data failed to show any statistically significant difference between units "A" and "B".

The results utilizing the Acid Stripping Method as a modification of Activated Sludge Process indicate that phosphorus can be removed from waste water by this method. Total P removals in this test generally range from 40% to 80%.

As mentioned, the process necessitates the release of soluble and hydrolyzable phosphorus to double the amount in the influent, hence, the supernatant wasted from the stripping and wash tank contain a low BOD and suspended solids, but high phosphorus content. The phosphorus could be removed by chemical precipitation through the addition of ferric chloride or some other suitable chemical. As only the stripped phosphate sludge with a suspended solids concentration of 15,000 mg/l is returned to the aerator, the hydraulic load on the aerator is decreased. During these tests, the DO in the Aerator was held between 4 to 6 ppm. It has been noticed that high aeration rates result in poor settling of the floc in the secondary clarifyer, and this necessitates the addition of polymer.

The condition of the bacteria during the operation was studied by Dr. H. W. Rossmoore, Biologist from Wayne State University. In Table V are the results of the number of bacteria per ml. in the mixed liquor. It is his opinion that as long as the pH is not lowered beyond pH 4.8, the bacteria are present in sufficient numbers to carry out their purpose in the activated sludge process.

CONCLUSIONS

(1) Biological removals of phosphorous should reach 60 - 70% under properly controlled conditions. Further studies with modifications may show 80% removals.

(2) The best mechanism found for removing phosphorous from the bacterial cell was by acid stripping, which apparently had no lasting effect on bacterial metabolism

(3) Biological release under anaerobiosis was found to be adequate only when the sludge was held anaerobic for a period of days. Closer control by monitoring ORP would probably result in a more effective process.

(4) True anaerobiosis did not exist during the study because of short detention times.

(5) During the first phases of the study, two pilot plants were operated in parallel. During this time the plant in which acid stripping was practiced did show higher phosphate removals than the control plant. This would indicate that removals were of a biological nature and not caused by a chemical precipitation.

(6) Optical and electronic microscopic examinations of activated sludge organisms before, during and after so-called "luxury uptake" ought to establish once-and-for-all, the fate of sorbed phosphorous and so resolve the question of whether or not "luxury uptake" is a real or imagined phenomenon.

(7) Monitoring of the microbial population periodically during the study has not indicated any untoward effects on viability of appearance produced by the acid-stripping procedure.

(8) Further study on biological phosphorous uptake is recommended and should be conducted using both acid stripping and anaerobiosis.

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